

A DIGITAL ENVELOPE DETECTION FILTER FOR BLOOD PRESSURE MEASUREMENT

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Abstract- We presented a digital envelope detection filter (EDF) for blood pressure measurement. This method was applied to volume oscillometric signals which were acquired from air-filled occlusive finger cuff. In case of using the EDF, we could reduce difference error and standard deviation by 30~40%.

Keywords - Digital envelope detection filter, Volume oscillometric, Blood pressure

I. INTRODUCTION

The oscillometric method is one of the most widely used indirect techniques for automatic measurement of arterial blood pressure.[1][2] Especially, the blood pressure measurement in finger artery offers some advantages with respect to the blood pressure measurement in brachial artery. The cuff that has to be inflated becomes much simpler to fit on a finger than upper arm. And this provides much less discomfort for the patient. But contracted finger artery affects true mean blood pressure. This tends to overestimate mean blood pressure when the Maximum Oscillometric Criterion (MOC) is used.[3]

Another problem associated with measurement of blood pressure using finger artery is motion artifact. This makes measurement of MOC inaccurate. Most methods for envelope recovery from signals rely only upon peak detection followed by low pass filtering to remove the carrier and to provide smoothing.[4] Typically, this is rectification followed by a RC network. When carrier frequency is large relative to modulation frequency, this approach presents no problem.[5] The frequency of pulse wave is not large relative to MOC. And volume oscillometric signal which is acquired from finger artery, has motion artifact due to respiration, speaking, movement. So we investigated envelope detector which is robust to noise signal and detected envelope which does not increase the carrier frequency.

II. METHODOLOGY

According to the principle of signal envelop formation, an important step to form the envelop of signals is to get the Hilbert transform of signals.[6] Let $x(t)$ represent an input signal which should be envelope detected. Hilbert transforming $x(t)$ generates a new function $g(t)$. These form the real and imaginary components of a complex function $z(t)$.

$$z(t) = x(t) + jg(t) \quad (1)$$

and the envelope of $x(t)$ is the magnitude of Eqn.(1)

$$|z(t)| = \sqrt{x(t)^2 + g(t)^2} \quad (2)$$

Computing the Hilbert transform requires direct and inverse Fast Fourier Transform.(FFT)[7] This method yields best accuracy but is rather slow for real-time application. In fact, Hilbert transform can be considered as a 90° phase shifter. So, real-time application use a FIR or IIR filter, designed as a Hilbert transformer, to obtain an approximation to the analytical signal.[8]

We designed a 4th order IIR digital Hilbert transformer using Matlab 6.0.(The Mathworks Inc.) The sampling frequency of input data was 128Hz and the filter time delay is 27.3ms. After Hilbert transform filtering, the envelope signal was calculated from the vector magnitude of analytic signal which consists of the real and imaginary part of signal.

Proposed envelope detection algorithm is showed Fig. 2. Peak in every pulse is detected by a peak detector which captures the point, where the slope changes from positive to negative value, and then peak is examined comparing with the amplitude of previous peak. If the ratio of the present peak amplitude to the previous one is larger than 0.5, the peak is selected and saved. The selected peak values are averaged by 9 sequential point-moving window. This moving window eliminates the motion artifact in MOC. Finally this system uses the characteristic ratio of MOC to measure systolic, diastolic blood pressure.

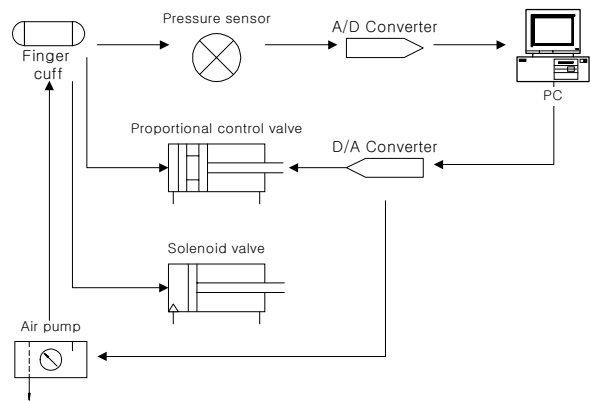


Fig. 1. System configuration of finger type blood pressure monitor

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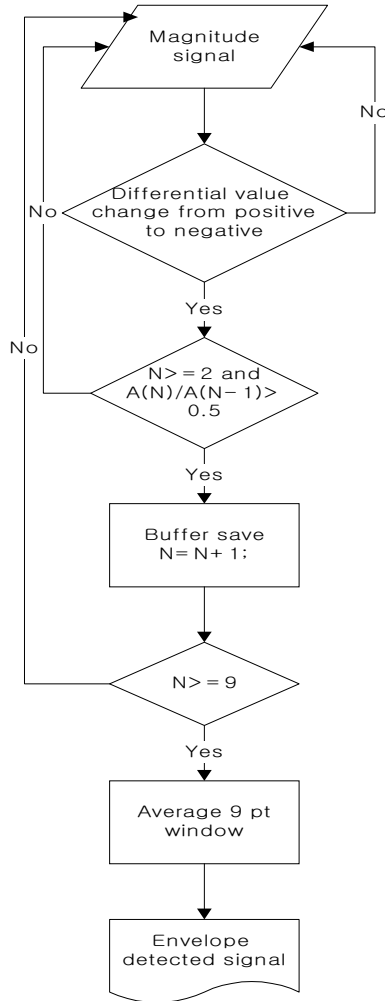


Fig. 2. Envelope detection algorithm

III. RESULTS

We obtained data using three methods to estimate blood pressure in 8 subjects.(22~37 years old; 5 men and 3 women) One method used a digital envelope detection filter(EDF). The second did not. In these two methods, the blood pressure was measured on finger. The third method is an indirect auscultatory method which measures blood pressure in brachial artery. To increase reliability of data, we repeated data acquisition 10 times for each method continuously. Then we compared the results of each method and were calculated the mean difference error and standard deviation.

Magnitude of analytic signal which was calculated by IIR Hilbert transform filter is showed in Fig. 3. The real part represents source signal and the imaginary part is negative frequency domain signal of source.

The peak position of each pulse affects largely the shape and maximum position of MOC in peak detection envelope. Motion artifact of finger induces the variation of peak amplitude frequently. Comparison of envelope which was used the digital EDF and only peak detector is shown in Fig. 4. This proves that 9 peak-point averaging minimizes the variation of peak amplitude and maximum amplitude position error.

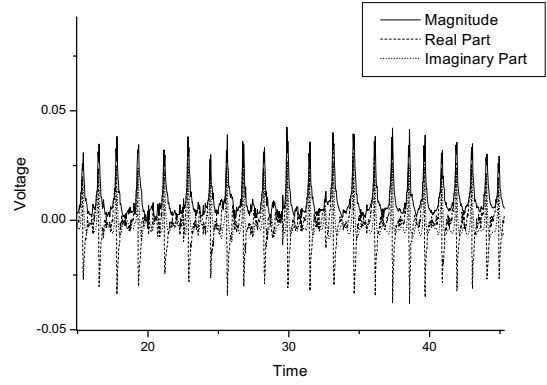


Fig. 3 Source signal(real part), Hilbert transformed signal(imaginary part) and magnitude of analytic signal

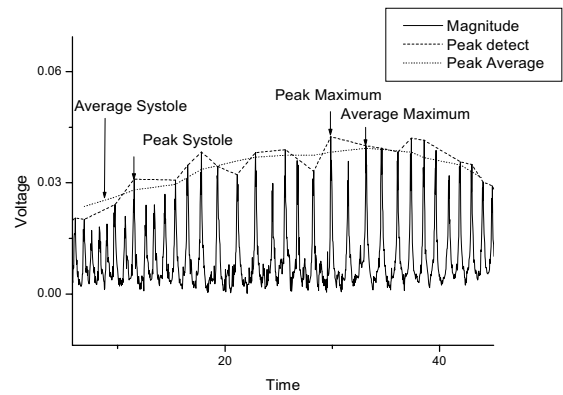


Fig. 4 Proposed digital envelope detection signal and peak detection envelope signal

Table 1.
SUMMARY OF COMPARISON OF ENVELOPE DETECTION(EDF)
FILTER METHOD AND NON-EDF METHOD

	EDF Method (\pm mmHg)		Non-EDF Method (\pm mmHg)	
	Systole	Diastole	Systole	Diastole
Mean difference	3.8	5.1	8.3	8.6
Standard deviation	6.5	5	9.3	9.6

When the results of EDF method and non-EDF one are compared with auscultatory method as reference, EDF provided smaller mean difference and standard deviation than Non-EDF did.

IV. DISCUSSION

A. Feasibility of digital envelope detection filter

In general, automatic blood pressure monitors have low performance Central Processor Unit. So, it is difficult to calculate Hilbert transform and to get the envelope of MOC in real time operation. For this reason, most blood pressure monitors use analog envelope detector. But when EDF is used, it is easy to implement digital envelope

detection in real time.[4][5] In further study, we will apply EDF using a 8 bit micro-controller which measures arterial blood pressure.

B. Error factors of oscillometric algorithm

Measurement of blood pressure in finger artery based on MOC has multiple variables which may affect the accuracy of the mean blood pressure obtained using air-filled occlusive cuff. The error depends on the arterial pressure pulse amplitude, as well as on the difference of the shape indices between arterial pressure pulse and arterial pressure-volume curve.[9][10] The changes of pressure-volume curve is initiated by a local vasoconstriction.[11] Another factor which affects accuracy of the measurement of mean blood pressure is a specific 'pulse wave amplification'. This can occur as a result of pulse wave reflection in the finger arterial system.[11] During the specific tests such as single deep breathing or the cold stress test, MOC-based finger mean blood pressure tends to be overestimated.[12]

So, we have to establish improved analysis models to consider various error factors of oscillometric algorithm, blood pressure monitoring using finger artery.

V. CONCLUSION

We developed a finger type blood pressure measurement system using volume oscillometric algorithm. Especially, digital EDF is applied to improve accuracy of system. Feasibility of digital EDF was tested for 8 subjects clinical test in comparison with Non-EDF method. Results of experiment proved that digital EDF was useful tool to improve accuracy of blood pressure measurement.

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